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RELATION OF DUST FUNGICIDES TO FLOW OF SMALL GRAINS THROUGH DRILLS AND TO DRILL INJURY

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INTRODUCTION

Since the advent of copper carbonate as a fungicide for the control of bunt in wheat, many complaints have been received from farmers that this dust greatly retards the flow of wheat through the drill and thus causes too low a rate of seeding. When sowing dusted wheat, many farmers open the drill to the setting used for barley, in order to compensate for this observed reduction. It also has been reported that drills frequently have been broken by treated wheat clogging the feeding gears or through the abrasive action of the dust on the moving parts. According to these reports, this breakage usually occurs when sowing is resumed after the drill containing dusted wheat has stood in the open overnight or during wet weather.

Gregory and Mayer [1] described several cases of drill injury in Indiana and attribute them either to the use of an excessive quantity of copper carbonate or to the fact that the treated grain in the drill became wet. They conclude from laboratory experiments and farm observations that dry dusted wheat will not injure the drill, but that moisture is an essential factor in causing the injury to drills when wheat dusted with copper carbonate is used.

Rodenhiser,[2] using a drill of the internal force-feed type, found that no drill injury followed the use of copper carbonate of the 20 per cent brand, but that when the 52 per cent brand was used the drive sprocket and two gear hangers were broken and the drive shaft twisted.

Mackie [3] states that the use of copper-carbonate dust retarded the flow of Hard Federation wheat, a short-kerneled variety, 20.7

[1] Gregory, C. T., and Mayer, I. D. observations on injury to drills by copper carbonate treated wheat. Ind. Acad. Sci. Proc. (1925) 35 : 265–267, illus. 1926.
[2] Rodenhiser, H. A. effectiveness of copper carbonate in controlling stinking smut of wheat. U. S. Dept. Agr., Off. Coop. Ext. Work and Bur. Plant Indus. Ext. Path. 4 : 23–26. 1927. [Mimeographed.]
[3] Mackie, W. W. methods of applying copper carbonate dust and results from those applications. U. S. Dept. Agr., Off. Coop. Ext. Work and Bur. Plant Indus. Ext. Path. 4 : 31–35. 1927. [Mimeographed.]

per cent, and of Baart wheat, a long-kerneled variety, 32.6 per cent. The rate of seeding had no effect on the relative degree of retardation. He does not mention drill injury.

In order to throw more light on this phase of seed treatment, experiments were conducted to determine, if possible, the effect of various dusts on the flow of grain through the drill and on the drill itself, and also the added effect of atmospheric moisture and rain.

MATERIALS AND METHODS

A drill (No. 1) which had the external type of force feed was mounted on a frame so that the wheels revolved freely. A ½-horsepower motor was used as the motive power. A jack reduced the speed of the drill wheel to approximately the number of revolutions per minute it would turn when being used in the field. The number of revolutions equivalent to seeding one-eighthieth of an acre was computed, taking into consideration the circumference of the drill wheel and the number of spouts used.

Purplestraw wheat was dusted with various chemicals at the rate of 2.5 ounces per bushel. The drill was set to sow 6 pecks of undusted wheat per acre. Wheat from each dusted lot was tried in the drill ten times. Each trial was equivalent to sowing one-eighthieth of an acre, thus making a total test of each lot of dusted wheat equivalent to sowing one-eighth of an acre. The drill was thoroughly cleaned after running each lot of wheat.

EXPERIMENTAL RESULTS

The average quantity of each of the dusted lots of wheat delivered and the amount and percentage of reduction of the seeding rate in comparison with the seeding rate of undusted wheat are set forth in Table 1.

TABLE 1.—*Effect of different fungicidal dusts on the flow of Purplestraw wheat through a drill before and after the seed was exposed to a relative atmospheric humidity of 90 per cent for 40 hours*

[The quantity of wheat delivered in each case was the average of 10 trials, each trial being the equivalent of sowing one-eighthieth of an acre]

No.	Treatment	Dry seed delivered			Humidified seed delivered			Reduction in delivery of humidified untreated and treated seed as compared with delivery of dry untreated seed	
		Quantity	Reduction caused by specified treatments		Quantity	Reduction caused by humidifying dry treated seed			
		Grams	*Grams*	*Per cent*	*Grams*	*Grams*	*Per cent*	*Grams*	*Per cent*
	Untreated	487			449			38	7.8
1	Ceresan	466	21	4.3	451	15	3.2	36	7.4
2	Copper carbonate	439	48	9.8	429	10	2.3	58	11.9
3	Coppercarb	442	45	9.2	430	12	2.7	57	11.7
4	Copper chloride	451	36	7.4	435	16	3.5	52	10.7
5	Copper oxychloride	464	23	4.7	455	9	1.9	32	6.6
6	Copper oxalate	453	34	7.0	447	6	1.3	40	8.2
7	Höchst	448	39	8.0	436	12	2.7	51	10.5
8	Copper naphthol	455	32	6.6	444	11	2.4	43	8.8
9	Smuttox	454	33	6.8	441	13	2.9	45	9.4
10	Abavit B	459	28	5.8	456	3	.7	31	6.4
11	Mercury C	451	36	7.4	449	2	.4	38	7.8

Of the 11 dusts used in this test, copper carbonate caused the greatest retardation in the flow of grain, approximately 10 per cent. With the drill set to sow 6 pecks (90 pounds) of undusted wheat per acre, this reduction would amount to about 9 pounds per acre, a decrease in the rate of seeding hardly sufficient to affect appreciably the acre yield [4, 5] unless the drill already was set at too low a rate of seeding.

It was thought, however, that atmospheric moisture might increase the retardation of grain flow through the drill. To determine this point, the different lots of dusted wheat and a quantity of undusted wheat were exposed to an atmospheric humidity of 90 per cent saturation for 40 hours. Then they were again put through the same drill tests as before. The results of these experiments also are shown in Table 1. It will be noted that the flow of the humidified undusted seed was reduced 7.8 per cent, which was more in comparison with the flow of the dry undusted seed than was the reduction in any humidified dusted lot in comparison with the flow of its corresponding dry lot, the largest difference in the latter case being 3.5 per cent when copper chloride was used. Three of the lots of dusted seed flowed through the drill better after humidifying than did the humidified undusted control. This is in agreement with the conclusions of Koehler and Shawl,[6] who found that under certain conditions some dusts seemed to have a lubricating effect. A test of the moisture content of the dusted and undusted seed, before and after being in the humidity chamber, indicated that the undusted seed absorbed slightly more moisture than did the dusted seed. These results indicate that unless the dusted wheat stands in the drill long enough to allow it to become set the absorption of atmospheric humidity alone is not likely to cause the difficulties occasionally reported by farmers who have sown dusted seed.

In carrying out further tests along this line, it was decided to restrict them to seed treated with copper carbonate, because this dust had caused the greatest retardation in the flow of seed through the drill, and because it was the dust about which most numerous complaints had been made in connection with trouble with drills.

In the next drill test wheat dusted with copper carbonate at the rate of 2.5 ounces per bushel was exposed for 1 hour to vapor from escaping steam and then allowed to remain in the drill for 20 hours, covered with a moist cloth. This treatment did not increase the reduction in the rate of flow of the dusted wheat, although the wheat was rather damp when it was put into the drill. (Table 2.)

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[4] LEIGHTY, C. E., and TAYLOR, J. W. RATE AND DATE OF SEEDING AND SEED-BED PREPARATION FOR WINTER WHEAT AT ARLINGTON EXPERIMENT FARM. U. S. Dept. Agr. Tech. Bul. 38, 20 p., illus. 1927.

[5] MARTIN, J. H. FACTORS INFLUENCING RESULTS FROM RATE- AND DATE-OF-SEEDING EXPERIMENTS WITH WHEAT IN THE WESTERN UNITED STATES. Jour. Amer. Soc. Agron. 18: 193–225, illus. 1926.

[6] KOEHLER, B., and SHAWL, R. I. THE EFFECT OF SOME SEED TREATMENTS ON THE WEAR AND ACCURACY OF DROP OF THE CORN PLANTER. Agr. Engin. 9: 45–46, illus. 1928.

TABLE 2.—*Effect of copper-carbonate dust, atmospheric humidity, wetting the grain, and combinations of these on the flow of wheat through a drill*

[The quantity of wheat delivered in each case was the average of 10 trials, each the equivalent of the quantity required for sowing one-eightieth of an acre]

Lot No.	Treatment of seed	Quantity delivered	Reduction due to treatment as compared with delivery of dry undusted seed
		Grams	*Per cent*
1	Undusted	487	
2	Dusted with $CuCO_3$ (2½ ounces per bushel)	439	10
3	Undusted, exposed to 90 per cent humidity 40 hours	449	8
4	Dusted, exposed to 90 per cent humidity 40 hours	443	9
5	Dusted, exposed to steam vapor 1 hour	440	10
6	Undusted, 7 per cent water added by spraying	302	38
7	Dusted, 7 per cent water added by spraying	341	30
8	Lot No. 6 dusted with $CuCO_3$ (5 ounces per bushel)	357	27
9	Lot No. 7 plus 14 per cent water, left in drill 4 days	362	26
10	Lot No. 9 plus 50 per cent water, left in drill 3 days; plus another 50 per cent water, left 2 days more	374	23
11	Undusted, treated same as lot No. 10	348	29

In order to create more extreme conditions, such as might obtain when seed is left in a drill in wet weather and exposed to rain, 3,500 grams of wheat, dusted with copper carbonate at the rate of 5 ounces per bushel, was sprayed with 250 cubic centimeters of water and then run through the drill at once. An equal quantity of undusted wheat received the same treatment. The flow of dusted wheat averaged 341 grams per trial, or 13 per cent more than the flow of undusted wheat similarly treated, which averaged only 302 grams per trial. (Table 2.)

The undusted moistened wheat was then dusted with copper carbonate at the rate of 5 ounces per bushel and again run through the drill. The average quantity delivered per trial was increased immediately from 302 grams to 357 grams. (Table 2.) In other words, copper carbonate seemed to accelerate the flow of the moistened grain instead of retarding it.

To this dusted lot, which had been previously moistened, another 500 cubic centimeters of water, equivalent to 14 per cent of the weight of the grain, was then added. This wheat, covered with a moist cloth, was allowed to remain in the drill for 96 hours (4 days). In running this lot through the drill the first and second trials yielded only 260 and 240 grams, respectively. This seemed to indicate that there was some clogging of the force-feeding mechanism. But the next trial yielded 385 grams, and this amount remained more or less constant in the 7 succeeding trials, the average of the 10 trials being 362 grams, or a reduction of 26 per cent as compared with the delivery of dry undusted seed. (Table 2.) There was no indication of the wheat "caking" in the drill, nor was any difficulty experienced in starting the drill, such as has been reported to occur in the field after wheat treated with copper carbonate had been left in the drill for some time.

In a final effort to clog the drill, 9,000 grams of wheat dusted with copper carbonate were placed in the drill and sprayed with 4,500 cubic centimeters of water. The wheat became thoroughly wet, and some of the water flowed through the grain spouts. The wheat was then covered with a wet cloth and allowed to remain in the drill for three days. Another 4,500 cubic centimeters of water was then added, and the wheat, covered as before, was allowed to stand for two more days. When the motor was started and the drill thrown into gear, the belt was thrown off repeatedly because the motor was not able to start the drill. It took considerable effort to turn the drill wheel by hand sufficiently to loosen the force-feeding rolls which apparently were clogged. Even then the grain did not flow freely until it was stirred thoroughly and the caked wheat picked out of the fluted gears. After this had been done the first trial yielded 328 grams, the next 366 grams, and the 10 trials averaged 374 grams (Table 2), or 23 per cent less than trials of dry undusted wheat and 14.8 per cent less than trials of dry wheat dusted with copper carbonate. An oven test showed that the wheat contained 21 per cent of moisture.

A similar test then was made with undusted wheat. The weather turned warm during this period, and some of the wheat began to sprout before the test was completed. Much greater difficulty was experienced in starting the drill than in the case of the moistened dusted wheat. The wheat would not flow through the drill until the fluted feed gears had been cleaned and the grain in the hopper thoroughly stirred. After this had been done the first trial yielded 328 grams and the second 338 grams. The average of 10 trials was 348 grams, or 28.5 per cent less than the average for dry undusted wheat and almost 7 per cent less than the average for wheat dusted with copper carbonate and similarly moistened. (Table 2.) The wheat contained 25 per cent of moisture, according to an oven test.

Gregory and Mayer [7] report that drill injury in Indiana has always been associated with the "internal or double-run grain feed" type of drill. Therefore, a drill of this type (No. 2) was used in further experiments with grain treated with copper carbonate.

In the first preliminary tests with this drill copper carbonate when applied at the rate of 2.5 ounces and 5 ounces per bushel, respectively, reduced the flow of wheat 16.2 per cent. The untreated wheat was run through the drill first, then the wheat which had been dusted at the 2.5-ounce rate, and finally the more heavily dusted wheat. In each case the average of 10 trials was taken as before. When undusted wheat was again run through the drill it picked up enough copper carbonate from the drill to retard its flow more than 7 per cent as compared with the delivery in the first trial. The brushes of the kernels were perceptibly tinged with copper carbonate.

It seems that a very light application of copper carbonate created enough friction among the kernels to retard somewhat the normal flow of the grain. In order to measure this friction in a relative way, Gregory and Mayer used the "slump test" and from this determined that the various brands of copper carbonate increased the friction in the flow of the wheat kernels from 23.4 to 37.8 per cent, while copper stearate increased it only 16.6 per cent.

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[7] Gregory, C. T., and Mayer, I. D. Op. cit.

The writer tried to measure this friction by determining with a stop watch the number of seconds required for 1,000 grams of each lot of wheat to flow through a glass funnel as compared with the time required by an equal weight of undusted seed. Every precaution was taken to eliminate variations due to manipulation. The average of 10 trials was taken. These results are shown in Table 3. The increase in the volume of this given weight of grain caused by the different treatments was arrived at by measuring the volume of each lot of seed after it had passed through the funnel into a graduated cylinder. These results also are shown in Table 3. There is a very apparent correlation between these two sets of data. The increased volume of the dusted wheat very evidently is due to increased friction keeping the kernels from settling closely together. However, there is a marked lack of correlation between these results and those shown in Table 1. This is especially true in the case of copper oxychloride, which in the funnel test caused a greater degree of retardation than any other dust, but which in the actual drill test (Table 1) caused less retardation than any other dust except one. The reason for this discrepancy was not determined.

TABLE 3.—*Effect of various dust fungicides on the volume of a given weight (1,000 grams) of Purplestraw wheat and on the friction between the kernels*

No.	Treatment	Test for volume			Test for friction		
		Volume of grain	Increase		Time [1]	Increase in time	
		C. c.	*C. c.*	*Per cent*	*Seconds*	*Seconds*	*Per cent*
	Untreated	1,240			22		
1	Ceresan	1,260	20	1.6	24	2	9.1
2	Copper carbonate	1,290	50	4.0	26	4	18.2
3	Coppercarb	1,280	40	3.2	25.7	3.7	16.8
4	Copper chloride	1,286	46	3.7	25.5	3.5	15.9
5	Copper oxychloride	1,300	60	4.8	27.5	5.5	25.0
6	Copper oxalate	1,296	56	4.5	26	4.0	18.2
7	Höchst	1,298	58	4.6	26.5	4.5	20.4
8	Copper naphthol	1,300	60	4.8	27	5.0	22.7
9	Smuttox	1,286	46	3.7	25.5	3.5	15.9
10	Abavit B	1,250	10	.8	23	1.0	4.5
11	Mercury C	1,256	16	1.3	23.5	1.5	6.8
12	Untreated (wet) [2]	1,420	180	14.5	37.4	15.4	70.0
13	Copper carbonate (wet) [2]	1,394	154	12.4	34.5	12.5	57.0

[1] Time required for the wheat to pass through a glass funnel.
[2] Moisture content of wheat, 30 per cent.

As in the case of drill No. 1, various methods were employed in an attempt to clog or to injure drill No. 2. As previously reported by Mackie,[8] setting for different rates of seeding had no appreciable effect on the percentage of retardation. Different rates of applying the copper carbonate, up to 20 ounces per bushel, were tried, both drills being used and Minsturdi barley and Culberson oats being included in the tests. These results are shown in Table 4.

[8] MACKIE, W. W. Op. cit.

TABLE 4.—*Effect of copper-carbonate dust, applied at different rates, on the flow of grain through (1) a drill with the external type of force feed and (2) a drill with the internal type of force feed*

[The quantity of wheat delivered in each case is the average of 10 trials, totaling the equivalent of the quantity required for sowing one-eighth of an acre]

Rate of application (ounces per bushel)	Drill No. 1						Drill No. 2					
	Weight of grain delivered			Retardation			Weight of grain delivered			Retardation		Acceleration in oats
	Wheat	Barley	Oats	Wheat	Barley	Oats	Wheat	Barley	Oats	Wheat	Barley	
	Grams	*Grams*	*Grams*	*Per ct.*	*Per ct.*	*Per ct.*	*Grams*	*Grams*	*Grams*	*Per ct.*	*Per ct.*	*Per ct.*
0	480	452	352	-------	-------	-------	494	330	244	-------	-------	-------
2	442	420	-------	7.9	7.1	-------	411	-------	-------	16.8	-------	-------
4	452	425	312	5.8	6.0	11.4	399	311	249	19.2	5.8	2.0
8	456	430	311	5.0	4.8	11.6	390	317	259	21.0	3.9	6.1
12	467	435	312	2.7	3.8	11.4	382	322	255	22.6	2.4	4.5
16	476	433	315	.8	4.2	10.5	379	321	259	23.3	2.7	6.1
20	478	432	317	.4	4.4	10.0	375	320	261	24.1	3.0	7.0

In drill No. 1 both the wheat and the barley flowed better as the rate of application was increased. The oats were retarded most when the rate of application was 8 ounces per bushel and least at the 20-ounce rate. In drill No. 2 the flow of wheat was retarded more as the rate of application was increased, while the flow of oats actually was accelerated by the use of copper carbonate, from 2 per cent at 4 ounces of dust per bushel to 7 per cent at 20 ounces per bushel. The flow of barley was retarded most when the dust was applied at the rate of 4 ounces per bushel and least when it was applied at the rate of 12 ounces per bushel. In no case, however, was there any indication of trouble with the drill even after wheat, dusted at the heaviest rate, had been left in the drill for several days. In these tests, however, the dusted grain was kept dry.

Two lots of wheat of 1 bushel each, one undusted and the other dusted with copper carbonate at the rate of 5 ounces per bushel, were exposed to a saturated atmosphere for several days and then run through drill No. 2. The small amount of moisture, less than 2 per cent, absorbed by this relatively large bulk of undusted and dusted wheat had no apparent effect on the flow of either lot through the drill in comparison with the flow of its respective unhumidified control.

Each of these same two lots of wheat then was sprayed with a quantity of water equivalent to 25 per cent of its weight and allowed to stand in a covered tub for 18 hours. At the end of this time the wheat had absorbed most of the water and, according to an oven test, contained 30 per cent of moisture. Both lots were then placed in the drill, each lot in the same section in which it had been tested before being moistened. The wheat flowed through the drill very poorly, just as in another test it was greatly retarded in its flow through the glass funnel. (Table 3.) Occasionally it was necessary to tap the drill with a hammer to keep the grain flowing. The results of this and subsequent drill tests at intervals of several days are shown in Table 5. As in the case of drill No. 1, the moistened dusted wheat flowed through the drill much more readily than the

moistened undusted wheat. At no time, however, was there any indication of injury to the drill, even after the moist grain had lain undisturbed in the drill for three days. After eight days the undusted wheat began to spoil, and therefore these tests were discontinued.

TABLE 5.—*Retardation of the flow of undusted wheat and of wheat dusted with copper carbonate through drill No. 2 after the moisture content of each lot of wheat had been increased to 30 per cent and the wheat allowed to remain in the drill for extended periods, in comparison with the flow of dry undusted and dusted wheat, respectively*

[The quantity of wheat delivered in each case was the average of 10 trials, the total being the equivalent of the quantity required for sowing one-eighth of an acre]

Items of comparison	Undusted wheat				$CuCO_3$ dusted wheat			
	Lot 1	Lot 2	Lot 3	Lot 4	Lot 1	Lot 2	Lot 3	Lot 4
Interval after wetting.....hours..	18	66	138	186	18	66	138	186
Moisture.....per cent..	30	30	28	26	30	30	28	26
Quantity of wheat delivered.grams..	282	233	276	265	294	282	289	276
Reduction.....do....	190	239	196	207	106	118	111	124
Reduction.....per cent..	40.3	50.6	41.5	43.9	26.5	29.5	27.8	31

In a final effort to cause injury to a drill of the internal force-feed type by the use of copper carbonate, several bushels of wheat were treated with this dust at the rate of 5 ounces per bushel and run through drill No. 2 continuously for eight hours on each of six consecutive days. The wheat remained in the drill overnight. Additional quantities of copper carbonate were added at times to compensate for the amount passing off into the air. Care was taken to keep the bearings of the drill well oiled.

At no time during this test was any difficulty experienced with the drill. It was started each morning by the ½-horsepower motor without any preliminaries, such as rocking the drill, turning the wheels by hand, or stirring the wheat in the hopper. The drill was under cover, which eliminated the possibility of trouble that might have been caused by dew or rain.

After six days the drill was carefully cleaned and closely inspected for any possible injury. None whatever could be found. The bearings were in good condition, and no parts were broken or excessively worn.

CONCLUSIONS

These results indicate that while some of the fungicidal dusts used retarded the flow of grain through the drill more than others under the conditions of this experiment, none of them caused a sufficient decrease in the quantity of dry dusted grain sown to affect appreciably the acre yield or to necessitate any change in the setting of the drill when sowing above 6 pecks per acre. This is true because, according to Leighty and Taylor [9] and Martin,[10] more abundant stooling and larger heads and kernels, resulting from more space per plant, practically compensate for the slightly fewer plants per acre,

[9] LEIGHTY, C. E., and TAYLOR, J. W. Op. cit.
[10] MARTIN, J. H. Op. cit.

unless seed of poor viability is used or a thicker stand is needed to suppress weeds.

From the data presented it is evident that dry dusted wheat flows through the drill more readily and requires less change in the drill setting than wheat which has been subjected to the wet formaldehyde treatment and sown while still slightly wet. This is shown by the greater decrease in the flow of moistened wheat. (Tables 2, 3, 5.) The reduction in stand due to seed injury commonly caused by formaldehyde also must be considered in this comparison. In fact, according to the above results, dry dusted wheat should require no alteration in the drill setting unless the rate of seeding is 6 pecks per acre or less, in which case it would not be amiss to increase the rate of seeding by 1 peck per acre.

According to the results of these experiments, dry dusted seed is not likely to cause injury to the drill even after it has remained in the drill for several days, unless the drill is allowed to stand out in dew or rain so that the seed becomes wet. However, under the conditions of these experiments wet undusted seed caused more difficulty than wet dusted seed.

Drill trouble undoubtedly can be avoided by not allowing grain to stand in drills in the open for long periods, especially in rainy weather. If this does occur, however, care should be taken to stir the grain thoroughly before sowing and to loosen the gears by rocking the drill wheel back and forth by hand. In the drill with external force feed the feed gates should be opened to remove the grain that may be caked about the feeding gears. It is important that the drill bearings be oiled frequently when dusted wheat is being sown, especially in wet weather. This is commonly neglected by farmers.

If these precautions are taken, they should eliminate any serious difficulties in sowing dusted grain or, for that matter, in sowing grain which has not been dusted, for cases of drill injury had been known to occur before the advent of copper carbonate as a seed disinfectant.

Drills should be cleaned thoroughly at the end of the seeding season.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

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